INDOOR AIR QUALITY ASSESSMENT

Hull Public Library
9 Main Street
Hull, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
July 2005

Background/Introduction

At the request of Daniel Johnson, Director for the Hull Public Library (HPL), the Center for Environmental Health (CEH) of the Massachusetts Department of Public Health (MDPH) provided assistance and consultation regarding conditions at the HPL, 9 Main Street, Hull, Massachusetts. Concerns of poor indoor air quality and mold prompted the request. On March 4, 2005, a visit to conduct an indoor air quality assessment was made by Michael Feeney, Director of CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program.

This two-story building was constructed as a home by the poet John Boyle O'Reilly in 1889 and was later converted into the HPL. An addition was added to the western wall of the original structure in 1981. An elevator was added to the 1981 addition in 2003. The library occupies both floors of the original building and the 1981 wing. The original building also contains a small cellar that contains the furnace and a full attic. The 1981 wing has both an attic and subfloor crawlspace. A small, detached utility shed is located near the rear of the building. Windows are openable throughout the HPL.

Methods

Air tests for carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The HPL has a staff of 5 and is visited by approximately 50 people daily. Tests were taken under normal operating conditions. Results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) of air in all areas surveyed, indicating adequate air exchange; however, no mechanical ventilation systems exist in the building. Ventilation is provided by openable windows. Ceiling fans are installed in several rooms to aid in air circulation. The original building is heated by cast iron radiators (Picture 1). The 1981 wing is heated by two wall-mounted electric heaters (Picture 2).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or has openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings ranged from 69^o F to 73 ^{o} F, which were within or very close to the MDPH recommended comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity readings ranged from 18 to 24 percent, which were below the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Significant ice dams were noted on roof edges (Picture 3) during the assessment, which can potentially lead to water penetration and subsequent damage. However, no water damage was observed in the attic, first or second floors of the building. The design of the Mansard-type roof places the lower section of the roof *outside* the plane of the exterior walls and the steep angle of the lower section of the roof helps prevent water accumulation inside the building envelope. It is likely that loose fiberglass insulation installed in the attic may enhance the creation of ice dams. The temperature measured in the attic was 70 ^{o}F, indicating significant heat penetration from the occupied areas as well as solar heating of the roof surface. Insulation was found hanging from the roof surface (Pictures 4 and 5). To prevent temperature transference insulation needs to be installed in contact with the intended surface.

Relative humidity measurements in the basement were 28 percent, with an outdoor relative humidity of 14 percent. These measurements indicate that a moisture source exists. A number of sources of standing water were noted in the basement, including a filled sump pump (Picture 6) and water in a trough that was cut along the foundation floor (Picture 7), reportedly as an aid to water drainage. With a variety of standing water sources in the basement, stored porous materials and/or building components can become chronically moistened. Of note is a gypsum wallboard (GW) material that was installed on the ceiling of the basement above the furnace, which showed signs of mold-colonization (Picture 8). GW is prone to mold colonization and should not be used as a building material in an area that accumulates water.

In order to become colonized with mold, a material must be exposed to water and remain moist. If sufficiently moistened, porous materials such as GW can support mold growth (US EPA, 2001). The US EPA and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

The HPL is located on a hill and appears subject to a number of potential moisture sources, including the terrain, that allow for water to penetrate into the basement. The following is a list of likely water sources:

- The gutters along the edge of the roof are either disconnected or empty at the base of the building. Gutters and downspouts should have a sufficient capacity for collecting and draining water from the roof. In addition, water should be emptied from downspouts in a manner that directs water away from the foundation instead of pooling at the base of the building. In this configuration, water accumulates against the foundation walls on the uphill side of the structure. Gravity directs the pooled water towards the building in a downhill direction.
- The freestanding shed at the rear of the building does not have a gutter/downspout system. As a result, rain from the shed is directed from its roof to the rear of the HPL, which increases water pooling along the foundation.
- Shrubbery was observed growing in close proximity to foundation walls. The growth of roots against exterior walls can bring moisture in contact with brick, eventually leading to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and/or masonry (Lstiburek & Brennan, 2001).

Each of these conditions can accumulate water against the flagstone foundation, which is readily water permeable. Therefore, the storage or use of any material that is prone to mold growth is not recommended unless remediation efforts are taken to prevent/reduce water penetration in the basement.

Having established the presence of mold colonized materials in the basement, the most likely pathway for these materials to travel from the basement into occupied areas is either through the basement door or seams in the stairwell leading to the second floor. Spaces were observed around the basement door, door frame and the ceiling of the stairway. The basement door is located on the first floor at the base of the stairwell leading to the second floor.

In order to explain how basement pollutants may be impacting the first and second floors, the following concepts concerning heated air and the creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air from outdoors through cracks or crevices in foundation walls or passive air vents (PAVs) in the foundation.
- As air rises, airborne pollutants will travel in the created air stream.
- As the range of temperature between hot and cold air increases, the rate of upward airflow increases.
- The operation of the heating system and elevator can create negative air pressure in occupied areas, which can draw air and pollutants from the basement.

Each of these concepts has influence on the movement of air.

A number of sources of unimpeded cold air penetrating to enhance the stack effect exist in the basement. An opening into the 1981 wing crawlspace exists in the basement wall near the furnace (Picture 9). Of note was the existence of PAVs in opposing walls of the basement. One PAV is located in the east basement wall beneath the porch at the front of the building. The second PAV is located in a bulkhead door on the west basement wall. The likely purpose of these vents is to provide combustion (make up) air for the furnace. In the experience of MDPH staff, one combustion air vent of sufficient size would be appropriate to provide combustion air for the furnace. In many buildings, the combustion air vent is configured with vents to limit direct wind-driven airflow into the furnace area. Too much airflow can pressurize the basement, forcing airborne pollutants in the basement into occupied areas through cracks, seams or crevices that exist between the basement and first floor. One PAV (the one beneath the porch) is sheltered, located in a location that would be minimally impinged by wind and appears more than likely sufficient to provide combustion air for the furnace.

In addition to the two PAVs, a box fan was operating in the basement during the assessment (Picture 10). It is likely the fan was being used to dry the basement by drawing air from the bulkhead PAV. The operation of the fan, in addition to the stack effect created by the openings in the basement walls, would likely pressurize the basement to force air, odors and other pollutants upwards toward the basement door and occupied areas.

Conclusions/Recommendations

The conditions found within the HPL raise a number of indoor air quality issues. The penetration of water combined with pressurization of the basement creates conditions that likely force basement air, odors and other pollutants into the occupied areas of the HPL. While some problems can be addressed immediately, others will require planning and resources.

In view of the findings at the time of the visit, the following recommendations are made:

1. Use of the fan should be discontinued to decrease pressurization of the basement.
2. Remove the GW from the basement ceiling as planned. Use a material other than GW (e.g., cement board) that is not prone to mold growth as a replacement material.

3. Render the basement door as airtight as possible using a door sweep and weather-stripping installed along the door/doorframe joint. Seal cracks in and around the basement side of the door frame with an appropriate sealant compound.
4. Render the ceiling and walls of the basement stairs as airtight as possible.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
6. Consider the following actions to prevent moisture penetration into the basement/crawlspace:
    a) Relocate the shed away from the rear of the building. If not feasible, install gutters and downspouts in a manner consistent with the below-listed recommendations.
    b) Fill in cracks and crevices along the foundation/exterior walls.
    c) Install gutters and downspouts to direct rainwater at least five feet away from the foundation. Gutters should extend along the entire roof edge.
    d) Remove foliage to no less than five feet from the foundation.
    e) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek & Brennan, 2001).
    f) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek & Brennan, 2001).

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001.

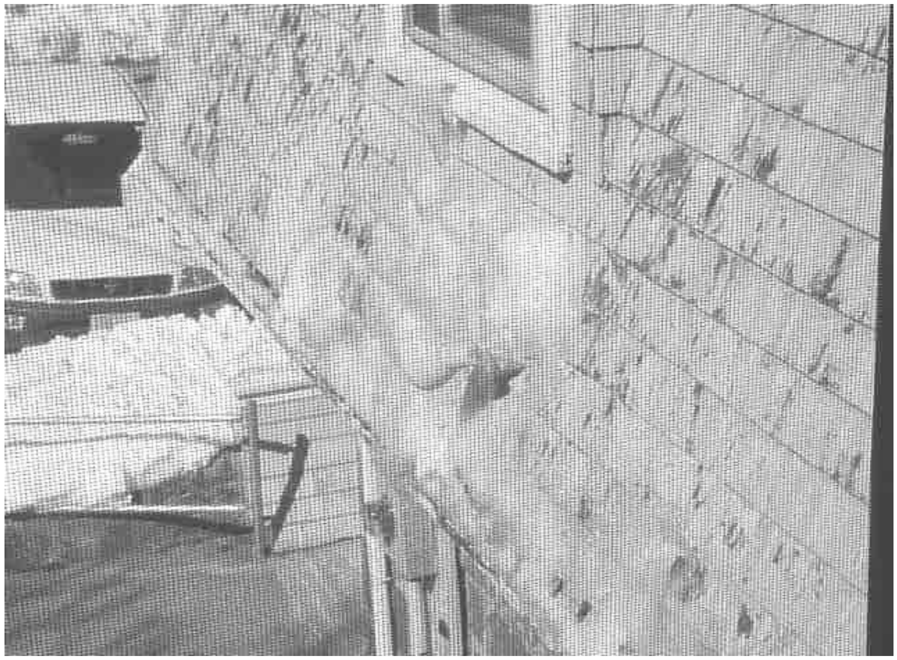
Picture 1

Cast Iron Radiator

Picture 2

Electric Heater

Picture 3



Ice Dams on Roof at Rear of Building above Bulkhead to Basement

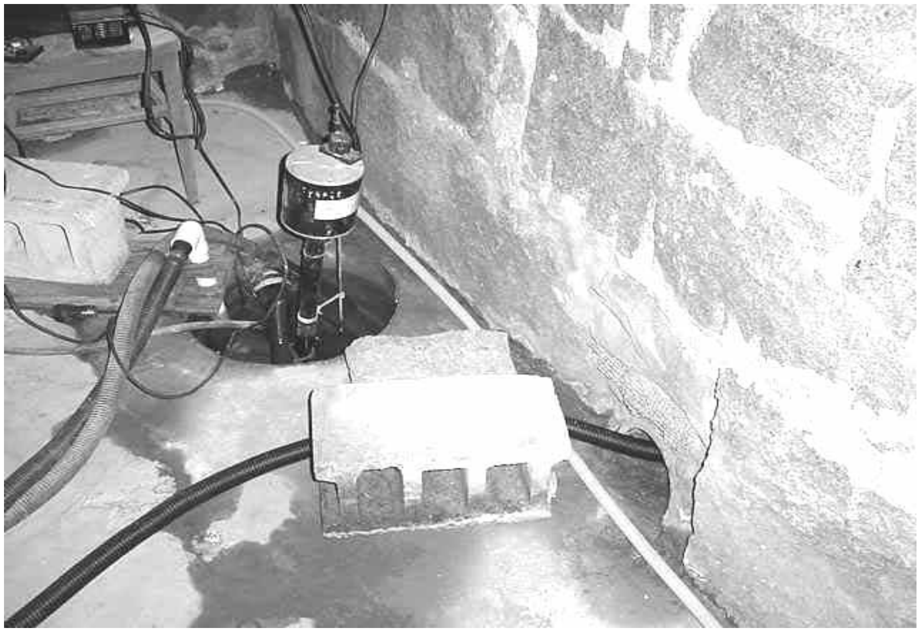
Picture 4

Insulation Hanging Between Rafters of Roof

Picture 5

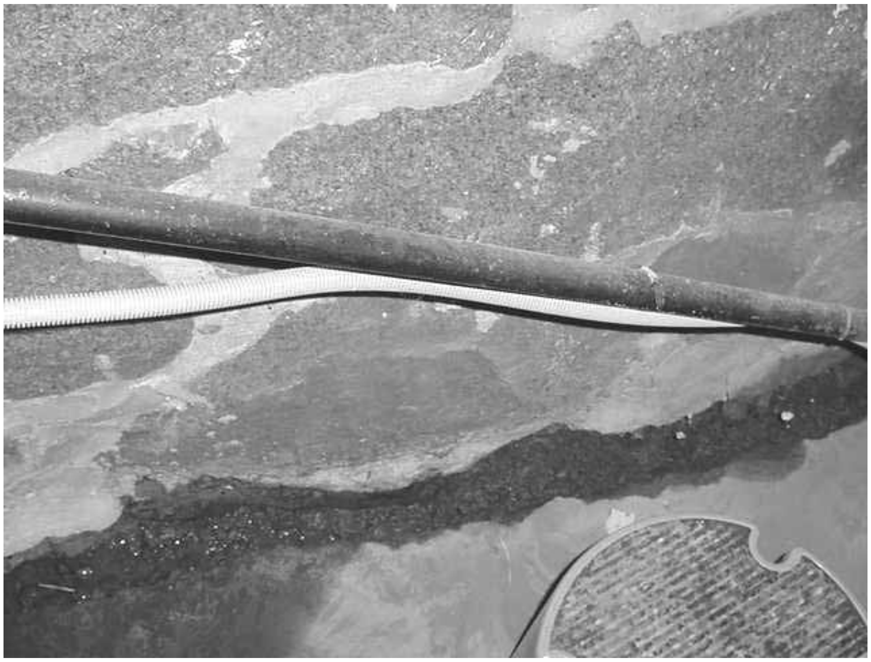
Insulation Hanging Between Rafters of Roof

Picture 6



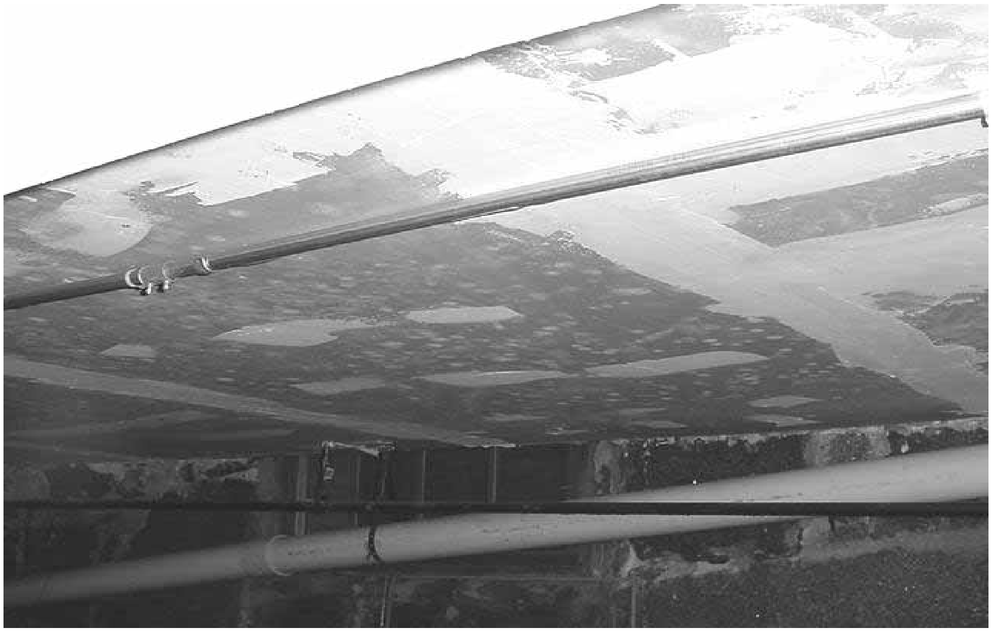
Sump Pump in Basement, Note Water Level and Drain to Remove Water in Foundation Wall

Picture 7



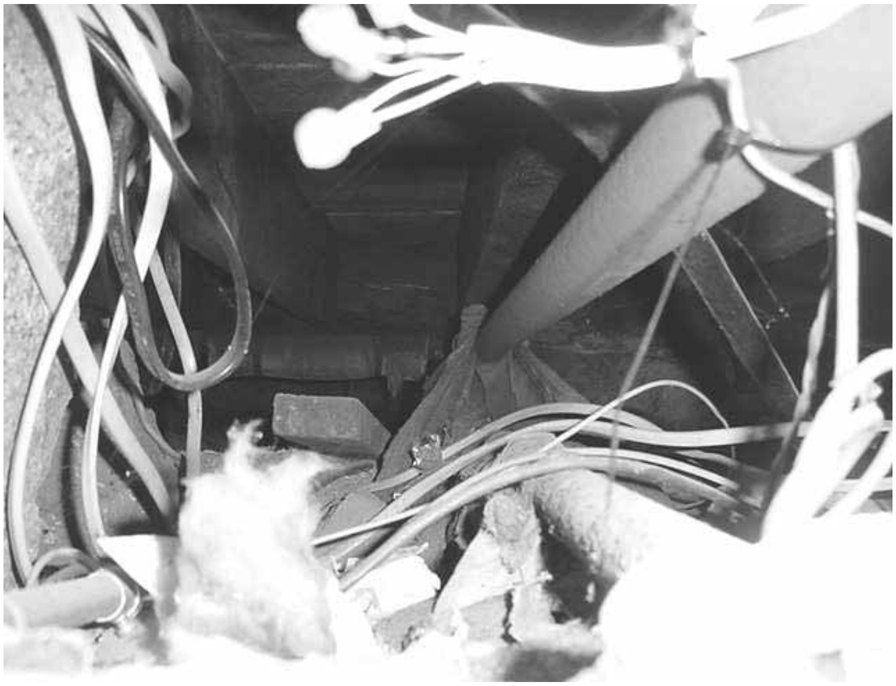
Water Trough Cut In Foundation Floor To Aid Water Drainage, Note Standing Water In Trough.

Picture 8



Mold Colonized Gypsum Wallboard on Ceiling of Basement

Picture 9



Opening into the New Wing's Crawlspace in Basement Wall near the Furnace

Picture 10

Box Fan Operating In Basement

TABLE 1

Indoor Air Test Results
Hull Public Library, Hull Massachusetts
March 4, 2005

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Outside (Background)	364	32	14					
Break room	664	69	24	2	Y	N	N	
Work station at stairwell landing, second floor	441	69	22	0	N	N	N	Ceiling fan off
Bookbinding/repair room	521	70	22	0	Y	N	N	Portable air filter
Rest room, second floor	512	70	21	0	Y	N	N	Water heater/custodial storage
Library Director's office	587	71	20	1	Y	N	N	Ceiling fan off
Periodicals room	507	72	21	0	Y	N	N	
Reference room	525	72	20	0	Y	N	N	
Stacks, second floor	535	72	21	0	Y	N	N	

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results
Hull Public Library, Hull Massachusetts
March 4, 2005

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Front desk, first floor	461	71	18	2	Y	N	N	Front door opening/closing during assessment
Large print/Local interest room	468	71	18	1	Y	N	N	Ceiling fan off
Video/Fiction Room	502	73	19	1	Y	N	N	Ceiling fan off
History/Science Area	513	71	20	2	Y	N	N	Portable air filter
Children's room	585	70	19	4	Y	N	N	Ceiling fan off
Basement	407	62	28	-	-	Y	N	Passive combustion air vent Box fan operating during assessment
Attic	462	70	22	-	-	-	-	Hanging insulation

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%